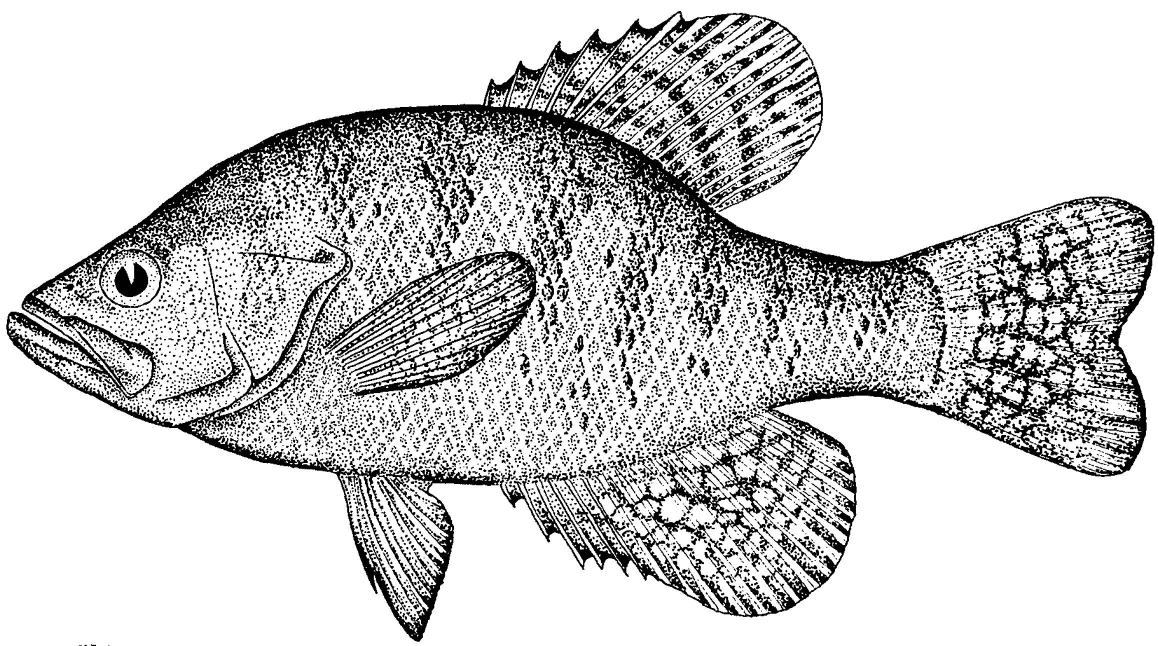
Biological Services Program

FWS/OBS-82/10.7
FEBRUARY 1982

HABITAT SUITABILITY INDEX MODELS: WHITE CRAPPIE



Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.

- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.

- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

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The Biological Services Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staffs, who provide a link to problems at the operating level; and staffs at certain Fish and Wildlife Service research facilities, who conduct in-house research studies.

FWS/OBS-82/10.7
February 1982

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by

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This report should be cited as:

Edwards, E. A., D. A. Krieger, G. Gebhart, and O. E. Maughan. 1982. Habitat suitability index models: White crappie. U.S.D.I. Fish and Wildlife Service. FWS/OBS-82/10.7. 22 pp.

PREFACE

The Habitat Suitability Index (HSI) models presented in this publication aid in identifying important habitat variables. Facts, ideas, and concepts obtained from the research literature and expert reviews are synthesized and presented in a format that can be used for impact assessment. The models are hypotheses of species-habitat relationships, and model users should recognize that the degree of veracity of the HSI model, SI graphs, and assumptions will vary according to geographical area and the extent of the data base for individual variables. After clear study objectives have been set, the HSI model building techniques presented in U.S. Fish and Wildlife Service (1981)[1] and the general guidelines for modifying HSI models and estimating model variables presented in Terrell et al. (1982)[2] may be useful for simplifying and applying the models to specific impact assessment problems. Simplified models should be tested with independent data sets, if possible.

Model reliability is likely to vary in different geographical areas and situations. The U.S. Fish and Wildlife Service encourages model users to provide comments, suggestions, and test results that may help us increase the utility and effectiveness of this habitat-based approach to impact assessment. Please send comments to:

Habitat Evaluations Procedures Group or Instream
Flow and Aquatic Systems Group
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2627 Redwing Road
Fort Collins, CO 80526-2899

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[1]U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S. Fish Wildl. Serv., Div. Ecol. Serv. n.p.

[2]Terrell, J. W., T. E. McMahon, P. D. Inskip, R. F. Raleigh, and K. L. Williamson. 1982. Habitat suitability index models: Appendix A. Guidelines for riverine and lacustrine applications of fish HSI models with the Habitat Evaluation Procedures. U.S. Fish Wildl. Serv. FWS/OBS-82/10.A. 54 pp.

CONTENTS

ACKNOWLEDGEMENTS

We would like to thank Corlin Cook, Fred Vasey, Richard Siefert, and Thomas Roush for reviewing the manuscript. Their review contributions are gratefully acknowledged, but the authors accept full responsibility for the contents of the document. Word processing was provided by Dora Ibarra and Carolyn Gulzow. The cover of this document was illustrated by Jennifer Shoemaker.

WHITE CRAPPIE (*Pomoxis annularis*)

HABITAT USE INFORMATION

General

The white crappie (*Pomoxis annularis*) is native to freshwater lakes and streams from the southern Great Lakes, west to Nebraska, south to Texas and Alabama, east to North Carolina, then west of the Appalachian Mountains to New York. It has been widely introduced outside this range throughout North America (Hubbs and Lagler 1958; Goodson 1966; Scott and Crossman 1973).

Age, Growth, and Food

White crappies mature at ages I-III (Eschmeyer et al. 1944; Hansen 1951; Siefert 1969) and have an average life span of 7-9 years (Pflieger 1975; Carlander 1977; Smith 1979). The largest recorded white crappie was 2.7 kg (Scott and Crossman 1973).

Fry begin feeding on copepods, rotifers, and algae. As the fish grow, they feed on a variety of zooplankton; at a length of approximately 120 mm, planktonic insects become the predominant item in the diet (Nurnberger 1930; Harper 1938; Crawley 1954; Burris 1956; Goodson 1966; Siefert 1968, 1969; Mathur 1972). Crappie over 150 mm feed almost exclusively on small fish (Crawley 1954; Marcy 1954; Burris 1956; Hoopes 1960; Neal 1962). Adults and juveniles forage over open water (Grinstead 1979).

Reproduction

Male white crappie construct and guard nests over a variety of substrates in river pools or bays, coves, and littoral areas of lakes and reservoirs near vegetation or other cover (Hansen 1965; Goodson 1966; Siefert 1968; Scott and Crossman 1973; Pflieger 1975). Nests have been observed at average depths from 10 to 420 cm (Hansen 1965; Vasey 1972). There is a positive correlation between spawning depths and water clarity (Vasey 1972). Nests may be 12-18 cm in diameter (Hansen 1965) or up to 76 cm in diameter (Vasey 1972), on substrates of clay, dirt, or gravel (Hansen 1965; Vasey 1972), usually near inundated vegetation (Vasey 1972) or filamentous algae (Hansen 1965; Wydoski and Whitney 1979). Spawning begins during March to July when water temperatures reach 13-14° C (Siefert 1968; Pflieger 1975). Peak spawning occurs at 16-20° C (Hansen 1965; Goodson 1966; Nelson et al. 1967). However, in a Missouri reservoir, white crappie were observed spawning in temperatures of 26° C at the nest (Vasey 1972).

Specific Habitat Requirements

White crappie are most abundant in lakes and reservoirs greater than 5 acres (Trautman 1957; Buck and Thoits 1970). The species also occurs in pools and overflow areas of larger rivers (Smith 1979). White crappie congregate in loose aggregations around submerged trees, stumps, brush, aquatic vegetation, and boulders (Trautman 1957; Hansen 1965; Pflieger 1975). Thus, cover can be beneficial for a crappie population (Hall et al. 1954; Goodson 1966).

The quality and quantity of available food is an important limiting factor for white crappie (Goodson 1966). Lacustrine habitat suitability for adequate food production may be described in terms of total dissolved solids (TDS). Jenkins (1976) reported a significant correlation between TDS levels of 100-350 ppm and high standing crop of white crappie.

White crappie are most numerous in base-level, low gradient rivers (Trautman 1957; Smith and Powell 1971). They are found frequently at gradients up to 0.5 m/km, less frequently at gradients to 1.0 m/km, and are absent at gradients above 1.3 m/km (Purkett 1958; Fleener et al. 1974; Funk 1975a, 1975b).

White crappie prefer low velocity areas, including pools and backwater sections of rivers (Scott and Crossman 1973). In Missouri, the species is abundant in sluggish pools or backwater areas located away from the main channel (Pflieger 1975). Slow to zero velocity sections of Oklahoma streams were preferred (Smith and Powell 1971).

White crappie were found at dissolved oxygen (DO) concentrations as low as 3.3 mg/l (Grinstead 1969) but were rarely found at 2.0 mg/l (Gebhart and Summerfelt 1974). A DO value of 5.0 mg/l describes an adequate lower limit to sustain optimal growth and survival (Stroud 1967; EPA 1976). In a lacustrine environment, oxygen levels must be adequate in the temperature strata that is selected by the species.

Although the white crappie appears to prefer moderately turbid waters (Hansen 1951; Schneberger 1972), the best growth occurs in clearer waters (< 50 JTU) (Hall et al. 1954; Hennemuth 1955; Hastings and Cross 1962). However, black crappie are usually predominate in clear waters where they occur with white crappie (Trautman 1957; Goodson 1966). White crappie generally predominate in southern, more turbid waters, where black crappie do not fare as well (Wydoski and Whitney 1979). White crappie can tolerate severe turbidity levels but appear to avoid them (Trautman 1957; Pflieger 1975).

A pH range of 5.0-9.0 is considered safe for freshwater fish (EIFAC 1969), and a range of 6.5-8.5 is essential for good production (Stroud 1967; EPA 1976). It is assumed that tolerance levels for white crappie would be similar to those for largemouth bass, which are frequently associated with white crappie (Carver 1966; Jenkins 1975). Calabrese (1969) reports that 50% mortality of largemouth bass (1.3 - 5.1 cm) occurred at pH's of 3.9 and 10.5 in 24 hour tests. Largemouth bass spawning is inhibited at pH levels of 5.0 and 10.0 (Swingle 1956; Buck and Thoits 1970).

The highest salinity in which white crappie were collected in the Mississippi delta area was 1.3 ppt (Carver 1966). White crappie had not been reported in previous collections in estuarine habitats in Louisiana.

Adult. In 90% of the streams where white crappie were found in the Mississippi River drainage and along the Atlantic coast, the average midsummer (July and August) temperatures were 17-30° C (Biesinger, personal communication), with a mean of 23.5° C. It may be inferred that these are adequate temperatures for growth of white crappie. Only 5% of the streams where white crappie were found had temperatures < 17° C. Adult white crappie showed a temperature preference of 26.5 to 27° C near a thermal effluent in

the Wabash River, Indiana (Gammon 1973). White crappie were not found above 31° C in a heated discharge (Profitt and Benda 1971).

Embryo. Siefert (1968) investigated the reproduction of white crappie in South Dakota hatchery ponds, and determined that survival of embryos was highest at temperatures of 18.9 to 19.4° C and lower at 22.8 and 14.4°

Fry. Specific temperature information for fry was not found in the literature. Their temperature requirements are assumed to be slightly more restrictive than those for juveniles and adults.

Juvenile. The upper lethal temperature for juvenile white crappie was found to be 33° C when acclimated at 29° C (Brungs and Jones 1977). These authors also reported that the preferred temperature in the laboratory was 28° C when acclimated at 27° C, and the optimal temperature for growth was 25° C. However, it is assumed that average mid-summer temperatures suitable for growth of adults are suitable for juveniles.

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The white crappie model is applicable throughout its native and introduced range in North America. The standard of comparison for each individual variable suitability index is the optimum value of the variable that occurs anywhere within the native and introduced regions. Therefore, the model will never provide an HSI of 1.0 when applied to water bodies in the northern regions where temperature related variables do not reach the optimum values found in the southern regions.

Season. The model provides a rating for a water body based on its ability to support a reproducing population of white crappie through all seasons of the year. The model will provide an HSI of 0.0 if any reproduction related variable indicates the species cannot reproduce.

Cover types. The model is applicable in riverine and lacustrine habitats as described by Cowardin et al. (1979).

Minimum habitat area. Minimum habitat area is defined as the minimum area of contiguous suitable habitat that is required for a species to live and reproduce. No attempt has been made to establish a minimum habitat size for white crappie.

Verification level. The acceptance goal of the white crappie model is to produce an index between 0 and 1 which we believe has a positive relationship to spawning success of adults and carrying capacity for fry, juveniles, and adults. In order to verify that the model output was acceptable, HSI's were calculated from sample data sets. These sample data sets and their relationship to model verification are discussed in greater detail following presentation of the model.

Model Description - Riverine

Food-cover component. Food and cover have been aggregated into one component because the variables within this component describe the suitability of both food and cover. In pools, overflow areas, and backwaters of rivers, cover (V_2) is important for resting areas and protection from predation. Cover also provides habitat for insects and small forage fish, important food for the black crappie. Percent pools (V_3) is included to quantify the amount of food/cover habitat.

Water quality component. Temperature (V_6, V_7), dissolved oxygen (V_9), pH (V_5), and turbidity (V_{11}) are included in the water quality component with salinity (V_{14}) as an optional variable. These parameters have been shown to affect survival, development, and growth of the species. Salinity (V_{14}) is an optional variable since it is not considered to be a potential problem in most areas where white crappie are found. However, salinity can affect growth and survival of the species.

Reproduction component. Cover (V_2) is an important reproduction component since spawning almost always occurs near vegetation or around submerged objects. Percent pools (V_3) quantifies the amount of spawning habitat. Temperature (V_8) and dissolved oxygen (V_{10}) are important parameters for the inducement of spawning and normal embryonic development.

Other component. The variables in this component are those which aid in describing habitat suitability for the white crappie, yet are not specifically related to life requisite components already presented. Stream gradient (V_1) is important since white crappie only occur in low gradient rivers and streams. Average current velocity (V_{12}) is included since waters preferred by the species have a very low average current velocity.

Model Description - Lacustrine

White crappie habitat quality analysis is based on basic components consisting of food, cover, water quality, and reproduction requirements. Variables that have been shown to affect growth, survival, abundance, or other measures of well-being of white crappie are placed in the appropriate component (Figures 1 and 2).

Food component. Average TDS (V_{13}) is included because TDS is a measure of general lacustrine productivity. Dissolved solids are a vital prerequisite for the development of the food chain.

Cover component. Cover (V_2) in shallower areas of the lacustrine environment provides the species with protection from predation and resting areas. Percent littoral area (V_4) quantifies the amount of cover habitat.

Water quality component. Same explanation as in the riverine model description.

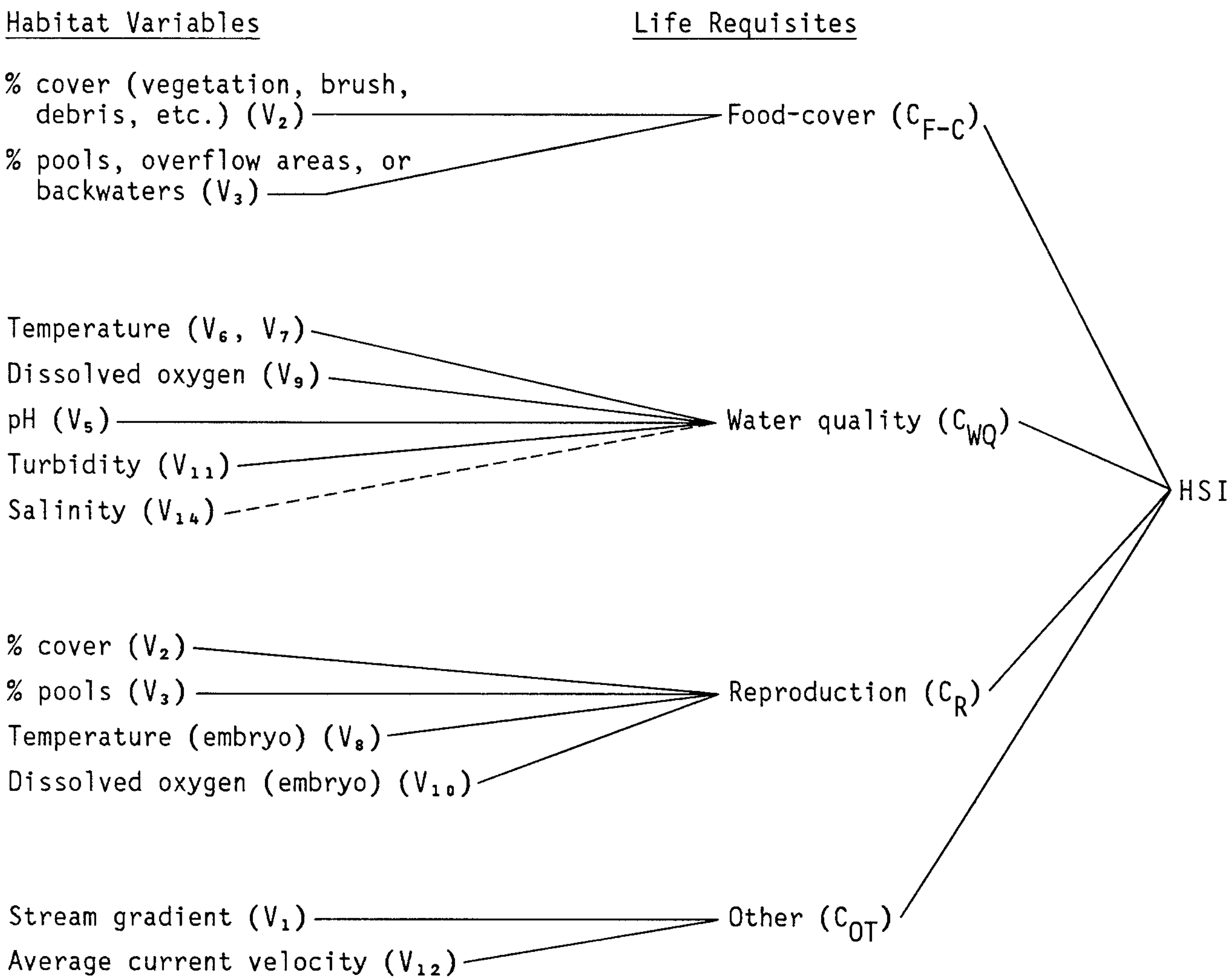


Figure 1. Tree diagram illustrating relationship of habitat variables and life requisites in the riverine model for the white crappie. Dashed line indicates optional variable in the model.

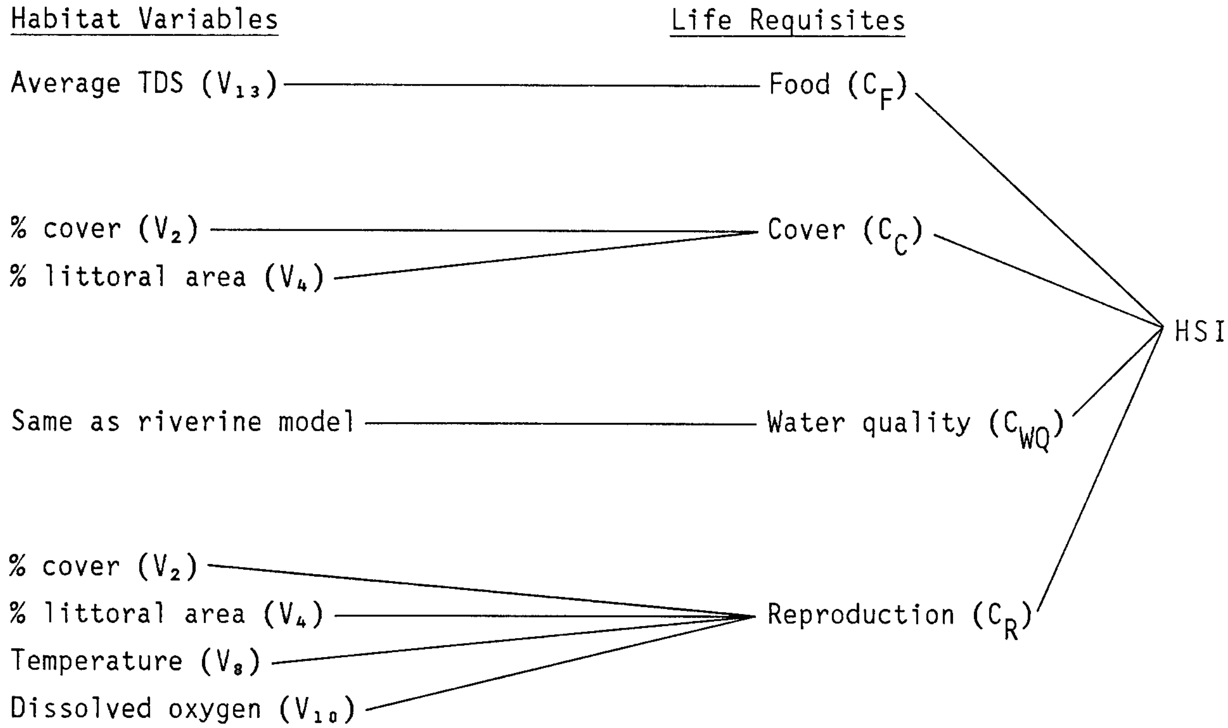
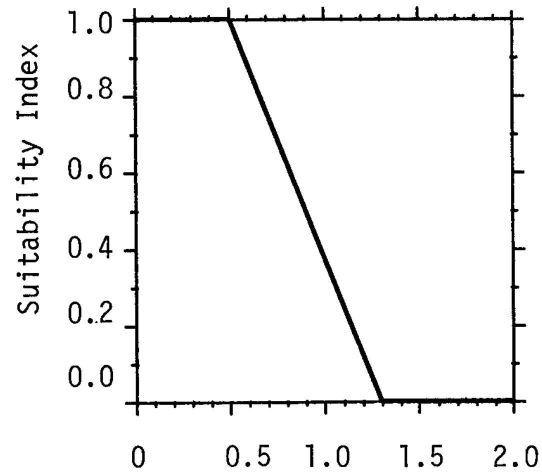
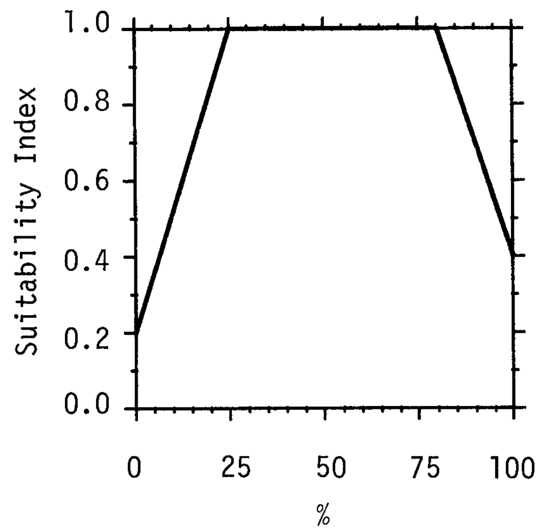


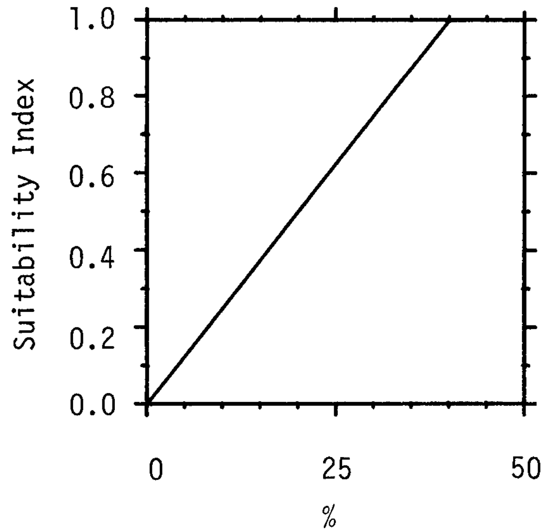
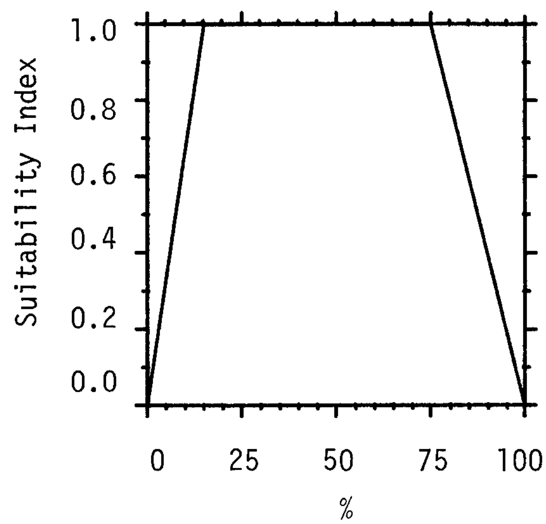
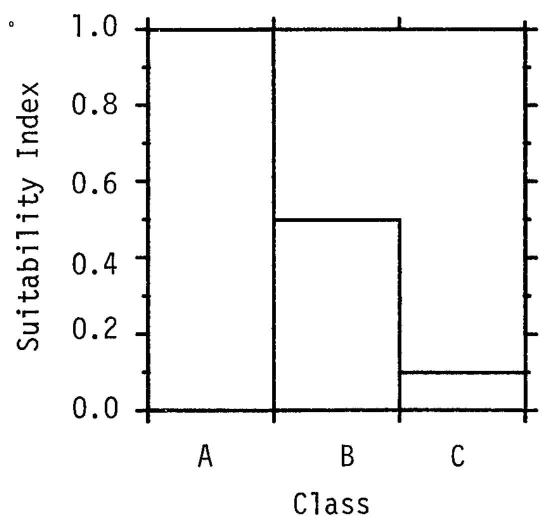
Figure 2. Tree diagram illustrating relationship of habitat variables and life requisites in the lacustrine model for the white crappie.

Reproduction component. Cover (V_2) in the form of vegetation, submerged logs, or brush is an important reproduction variable since spawning success seems to depend on the availability of some cover. Percent littoral area (V_4) quantifies the amount of cover habitat. Temperature for spawning (V_8) describes water quality conditions which affect embryonic development. Dissolved oxygen (V_{10}) affects survival and development of the embryo.

Suitability Index (SI) Graphs for Model Variables

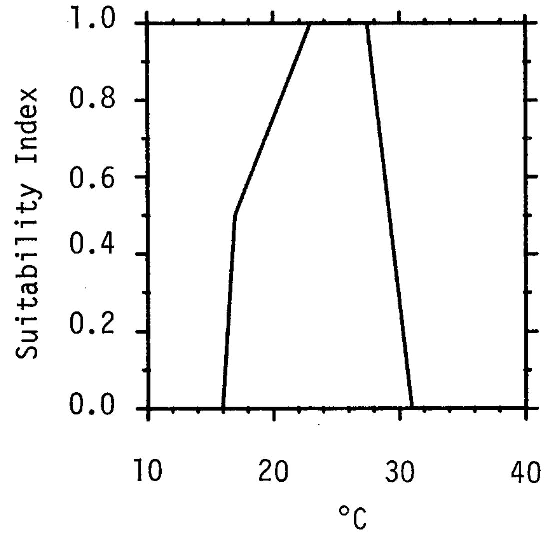
This section contains suitability index graphs for the 14 variables described above, and equations for combining selected variable indices into a species HSI using the component approach. Variables may pertain to either a riverine (R) habitat, a lacustrine (L) habitat, or both.

Habitat	Variable		Suitability Graph
R	(V_1)	Stream gradient within study area.	
R,L	(V_2)	Percent cover (vegetation, brush, debris, standing timber, etc.) during summer within riverine pools and lacustrine littoral areas (adult, fry, juvenile, embryo).	

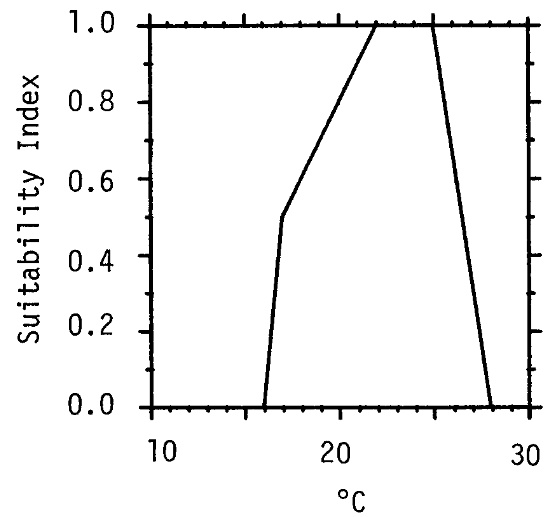
R	(V_3)	Percent pools, overflow areas, or backwaters during average summer flow.	
L	(V_4)	Percent littoral area.	
R,L	(V_5)	pH range during year. A) Stable; in 6.5 to 8.5 range. B) Never goes below 5.5 or above 9.0; with moderate fluctuation. C) pH frequently < 5.5 or > 9.0; with great fluctuations.	

R,L (V6) Average water temperature within epilimnion (L) or in pools or backwaters (R) during midsummer (July-August) (adult, juvenile).

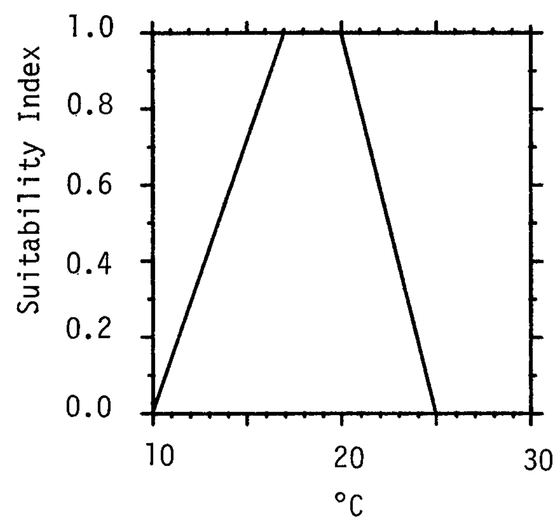
<u>Note</u>: Choose water temperature in epilimnion with highest SI rating, (i.e., where white crappie would most likely be found.)



R,L (V7) Average water temperature within littoral areas (L) or in pools or backwaters (R) during midsummer (fry).

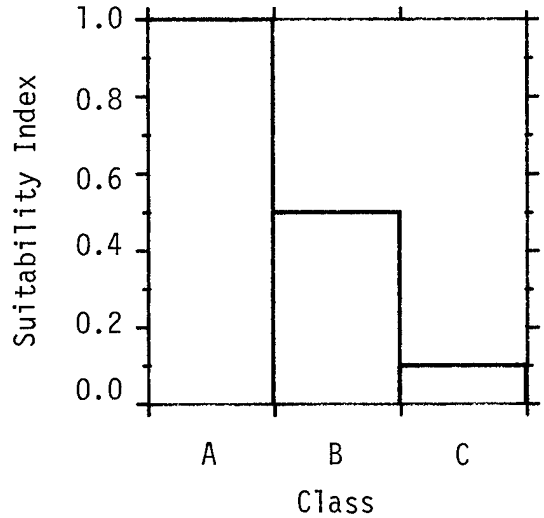


R (V8) Average temperature within littoral areas (L) or backwaters (R) during spawning (March to July) (embryo).



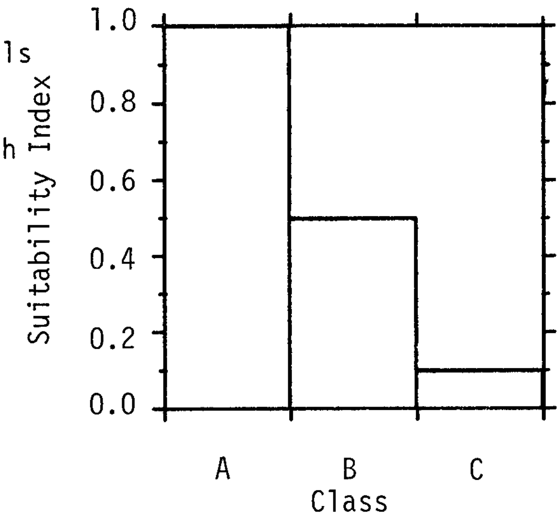
R,L (V$_9$) Minimum dissolved oxygen levels during midsummer (adult, fry, juvenile).

A) DO level always above 5 mg/l.
B) DO usually above 3 mg/l.
C) DO frequently below 3 mg/l.

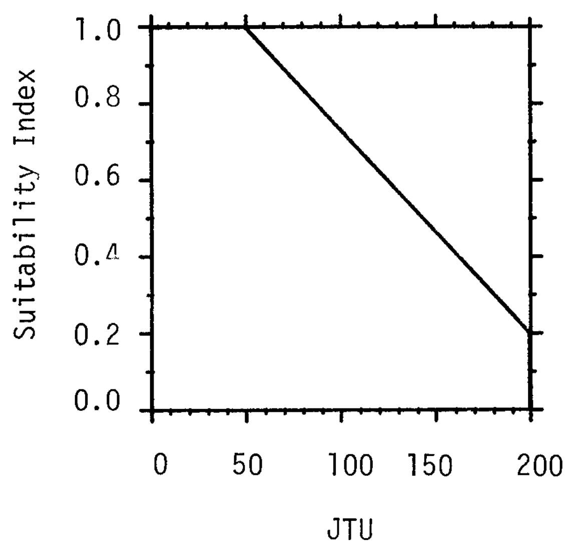


R,L (V$_{10}$) Dissolved oxygen levels within littoral areas (L) or backwaters (R) during spawning (March to July) (embryo)

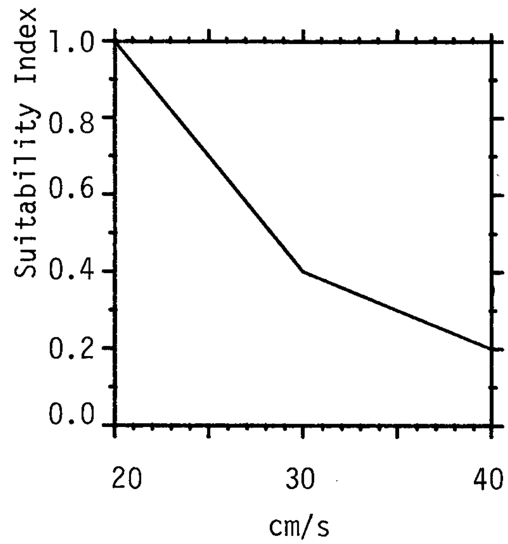
A) DO level always above 5 mg/l.
B) DO usually above 3 mg/l.
C) DO frequently below 3 mg/l.



R,L (V$_{11}$) Maximum monthly average turbidity during summer (May to August).

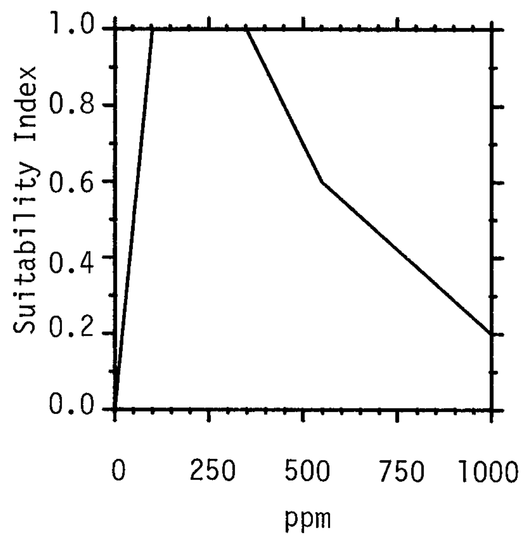


R (V12) Average current velocity within pools at 0.6 depth during average summer flow (May to August).



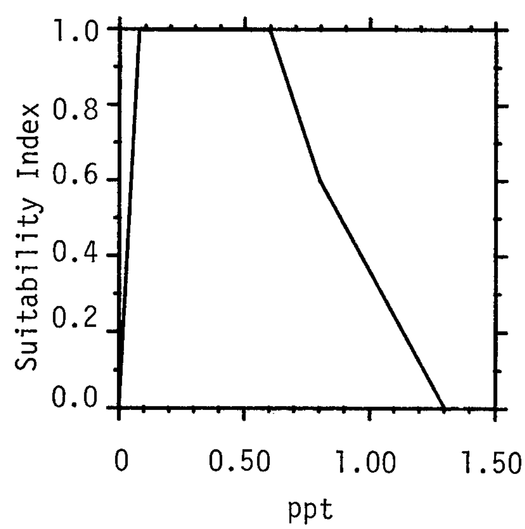
L (V13) Average TDS during midsummer.

Note: SI value should be lowered 0.2 if ionic concentration of sulfate-chlorides exceeds that of carbonate-bicarbonates.



R,L (V14) Maximum salinity during growing season (optional).

Note: V14 may be omitted if salinity is not considered to be a potential problem within the study area.



Riverine Habitat Suitability Index Equations

These equations utilize the life requisite approach and consist of four components: food-cover, water quality, reproduction, and other.

Food-Cover (C_{F-C}).

$$C_{F-C} = (V_2 \times V_3)^{1/2}$$

Water Quality (C_{WQ}).

$$C_{WQ} = \frac{V_5 + 2[(V_6 \times V_7)^{1/2}] + 2V_9 + V_{11}}{6}, \text{ or}$$

If $(V_6 \times V_7)^{1/2}$ or V_9 is ≤ 0.4, C_{WQ} equals the lowest of the following: $(V_6 \times V_7)^{1/2}$, V_9, or the above equation.

Note: If V_{14} (optional salinity variable) is added,

$$C_{WQ} = \frac{V_5 + 2[(V_6 \times V_7)^{1/2}] + 2V_9 + V_{11} + V_{14}}{7}$$

Reproduction (C_R).

$$C_R = (V_2 \times V_3 \times V_8^2 \times V_{10}^2)^{1/6}$$

Other (C_{OT}).

$$C_{OT} = (V_1 \times V_{12})^{1/2}$$

HSI determination.

$$HSI = (C_{FC} \times C_{WQ}^2 \times C_R \times C_{OT})^{1/5}, \text{ or}$$

If C_{WQ} or C_R is ≤ 0.4, then the HSI equals the lowest of the following: C_{WQ}, C_R, or the above equation.

Lacustrine Habitat Suitability Index Equations

These equations utilize the life requisite approach and consist of four components: food, cover, water quality, and reproduction.

Food (C_F).

$$C_F = V_{13}$$

Cover (C_C).

$$C_C = (V_2 \times V_4)^{1/2}$$

Water Quality (C_{WQ}).

$$C_{WQ} = \frac{V_5 + 2[(V_6 \times V_7)^{1/2}] + 2V_9 + V_{11}}{6}, \text{ or}$$

If $(V_6 \times V_7)^{1/2}$ or V_9 is ≤ 0.4, then C_{WQ} equals the lowest of the following: $(V_6 \times V_7)^{1/2}$, V_9, or the above equation

Note: If V_{14} (optional salinity variable) is added,

$$C_{WQ} = \frac{V_5 + 2[(V_6 \times V_7)^{1/2}] + 2V_9 + V_{11} + V_{14}}{7}$$

Reproduction (C_R).

$$C_R = (V_2 \times V_4 \times V_8^2 \times V_{10}^2)^{1/6}$$

HSI determination.

$$HSI = (C_F \times C_C \times C_{WQ}^2 \times C_R^2)^{1/6}, \text{ or}$$

If C_{WQ} or C_R is ≤ 0.4, HSI equals the lowest of the following:

C_{WQ}, C_R, or the above equation.

Sources of data and assumptions made in developing the suitability indices are presented in Table 1.

Sample data sets from which HSI's have been generated using the riverine HSI equations are given in Table 2. Similar sets using the lacustrine HSI equations are given in Table 3. The data sets are not actual field measurements, but represent combinations that could occur in a riverine or lacustrine habitat. The HSI's calculated from the data reflect what carrying capacity trends would be in riverine and lacustrine habitats with the listed characteristics. Thus, the models meet the acceptance goal of producing an index between 0 and 1 which is believed to have a positive relationship to the carrying capacity of fry, juvenile, and adult white crappie.

Interpreting Model Outputs

Habitats with an HSI of 0 may contain some white crappie; habitats with a high HSI may contain few. The white crappie HSI determined by use of these models will not necessarily represent the population of white crappie in the study area. This is because the standing crop does not totally depend on the ability of the habitat to meet all life requisite requirements of the species. If the model is a good representation of white crappie riverine or lacustrine habitat, then in areas where white crappie population levels are due primarily to habitat related factors, the model should be positively correlated with long-term average population levels. However, this has not been tested. The proper interpretation of the HSI is one of comparison. If two habitats have different HSI's, the one with the higher HSI should have the potential to support more white crappie than the one with the lower HSI, given the model assumptions have not been violated.

ADDITIONAL HABITAT MODELS

Model 1

Optimal riverine habitat for white crappie is characterized by the following conditions, assuming water quality is adequate: moderately turbid rivers (< 100 JTU), with a gradient less than 0.5 m/km; at least 40% pools or backwater areas; 25% cover within pools or backwater areas; and warm (> 20° C) mid-summer water temperatures.

Table 1. Data sources and assumptions for white crappie suitability indices.

Variable	and source	Assumption
V_1	Trautman 1957 Purkett 1958 Funk 1975	Stream gradients where white crappie are abundant are optimum. Gradients where fish are absent are unsuitable.
V_2	Hall et al. 1954 Trautman 1957 Goodson 1966 Pflieger 1975 Smith 1979	Because white crappie frequent areas with cover, some cover must exist for habitat to be suitable. Though not in the literature, it is assumed that too much cover would restrict foraging capabilities.
V_3	Goodson 1966 Scott and Crossman 1973 Pflieger 1975	Since white crappie are mainly found in pools, overflow areas, and backwaters of the main river channel, it is assumed that a certain percentage of these areas must exist for habitat to be suitable.
V_4	Hansen 1965 Vasey 1972 Pflieger 1975	Since spawning occurs in shallow areas near vegetation, a littoral area must exist for habitat to be suitable. Because of the preference of adult white crappie to move to deeper water after spawning, too much littoral area is assumed to be suboptimum to unsuitable.
V_5	Swingle 1956 (LMB) Stroud 1967 (freshwater fish) Calabrese 1969 (LMB) Buck and Thoits 1970	The pH levels that promote maximum growth and survival for freshwater fish are optimum. The pH levels that inhibit largemouth bass spawning are unsuitable.
V_6	Proffitt and Benda 1971 Gammon 1973 Brungs and Jones 1977 Biesinger 1980	Average mid-summer temperatures where white crappie are found are adequate for growth. Optimum growth occurs at the upper end of the temperature range for warm water fish. Temperatures that result in no growth or death are unsuitable. Juveniles acclimated at higher temperatures, and thus having a higher upper lethal temperature than adults, are assumed to not reflect natural conditions.

Table 1. Concluded

Variable and source		Assumption
V_7	Biesinger 1980	Average mid-summer temperatures where white crappie are found are adequate for growth. Optimum growth will occur near the upper end of the range.
V_8	Goodson 1966 Nelson et al. 1967 Siefert 1968 Pflieger 1975	Water temperatures that induce spawning are adequate. Temperatures that permit maximum survival of the embryo are optimum. Temperatures where no development occurs are unsuitable.
V_9	Stroud 1967 (freshwater fish) Grinstead 1969 Gebhart and Summerfelt 1974 EPA 1976 (freshwater fish)	Dissolved oxygen levels that promote maximum growth for freshwater fish are optimum. DO levels where the species may occur, but where growth and feeding are not maximum, are suboptimum.
V_{10}	Stroud 1967 (freshwater fish) EPA 1976 (freshwater fish)	Dissolved oxygen levels considered adequate for reproduction for freshwater fish are optimum. DO levels that are tolerated but where growth and survival are not maximum are suboptimal.
V_{11}	Hall et al. 1954 Hennemuth 1955 Trautman 1957 Hastings and Cross 1962 Goodson 1966 Grinstead 1969 Gebhart and Summerfelt 1974	Turbidity levels where the best growth occurs are optimum. Levels that are tolerated but which may affect feeding and growth are suboptimum. White crappie have been observed in very turbid conditions.
V_{12}	Smith and Powell 1971 Scott and Crossman 1973	Current velocities where white crappie are predominantly found are optimum.
V_{13}	Jenkins 1976	Average TDS levels that are associated with abundant food organisms are optimum. TDS levels that limit food production are suboptimum to unsuitable.
V_{14}	Carver 1966	Salinity levels where white crappie are most abundant are optimum. Levels that reduce populations are suboptimum to unsuitable.

Table 2. Sample data sets using riverine HSI model.

Variable		Data Set 1		Data Set 2		Data Set 3	
		Data	SI	Data	SI	Data	SI
Gradient (m/km)	V_1	0.1	1.0	0.2	1.0	0.7	0.8
% cover	V_2	15	0.6	20	0.8	15	0.6
% pools (summer)	V_3	15	0.4	70	1.0	10	0.3
pH	V_5	7.3	1.0	7.0	1.0	7.2	1.0
Temperature - adult, juvenile (°C)	V_6	26	1.0	26	1.0	16.3	0.3
Temperature - fry (°C)	V_7	24	1.0	24	1.0	16.8	0.4
Temperature - embryo (°C)	V_8	14	0.6	13	0.4	11.5	0.2
Dissolved oxygen - summer (mg/l)	V_9	4.5	0.5	5.5	1.0	9.5	1.0
Dissolved oxygen - spawning (mg/l)	V_{10}	4.5	0.5	6.0	1.0	10.0	1.0
Turbidity (JTU)	V_{11}	50	1.0	40	1.0	6	1.0
Velocity (cm/s)	V_{12}	27	0.6	22	0.9	30	0.4
Maximum salinity (optional) (ppt)	V_{14}	0.2	1.0	0.3	1.0	0.4	1.0
Component SI							
$C_{F/C}$ =			0.49		0.89		0.42
*C_{WQ} =			0.83		1.00		0.35
C_R =			0.53		0.71		0.44
C_{OT} =			0.77		0.95		0.57
HSI =			0.67		0.90		0.35**
HSI using additional Model 1 =			0.60		0.80		0.20

* Note: C_{WQ} does not include optional variable V_{14}
**Note: C_{WQ} < 0.4

Table 3. Sample data sets using lacustrine HSI model.

Variable		Data Set 1 Data	Data Set 1 SI	Data Set 2 Data	Data Set 2 SI	Data Set 3 Data	Data Set 3 SI
% cover	V_2	40	1.0	15	0.7	60	1.0
% littoral area	V_4	15	1.0	10	0.6	25	1.0
pH range	V_5	7.0	1.0	6.2	0.5	8.2	1.0
Temperature - adult, juvenile (°C)	V_6	26	1.0	19	0.7	28	0.9
Temperature - fry (°C)	V_7	23	1.0	17	0.5	24	1.0
Temperature - embryo (°C)	V_8	18	1.0	12	0.2	21.5	0.7
Dissolved oxygen - summer (mg/l)	V_9	7.4	1.0	3.8	0.5	5.2	1.0
Dissolved oxygen - spawning (mg/l)	V_{10}	7.8	1.0	4.3	0.5	5.5	1.0
Turbidity (JTU)	V_{11}	100	0.7	6	1.0	70	0.9
Average TDS (ppm)	V_{13}	50	0.5	25	0.3	186	1.0
Maximum salinity (optional) (ppt)	V_{14}	0.2	1.0	0.3	1.0	0.4	1.0
<u>Component SI</u>							
C_F =			0.50		0.30		1.00
C_C =			1.00		0.65		1.00
*C_{WQ} =			0.95		0.61		0.97
C_R =			1.00		0.40		0.89
<u>HSI Determination</u>							
HSI =			0.88		0.48		0.96
HSI using additional Model 2 =			0.80		0.20		1.00

*<u>Note</u>: C_{WQ} does not include optional variable V_{14}

$$HSI = \frac{\text{number of above criteria present}}{5}$$

Model 2

Optimal lacustrine habitat for white crappie is characterized by the following conditions, assuming water quality is adequate: lakes and reservoirs with warm (> 20° C) surface water; moderately turbid waters (< 100 JTU); abundant cover (> 25% of littoral area) in the form of aquatic vegetation, brush and trees; extensive littoral zone (≥ 15% of total area); and TDS levels of 100-350 ppm.

$$HSI = \frac{\text{number of above criteria present}}{5}$$

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. FWS/OBS-82/10.7	2.	3. Recipient's Accession No.

4. Title and Subtitle

Habitat Suitability Index Models: White crappie

5. Report Date February 1982

6.

7. Author(s) Elizabeth A. Edwards, Douglas A. Krieger, Glen Gebhart, and O. Eugene Maughan

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

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10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

Western Energy and Land Use Team
Office of Biological Services
Fish and Wildlife Service
U.S. Department of Interior
Washington, D.C. 20240

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

A literature review of the characteristics and life requisites of the white crappie (Pomoxis annularis) is followed by an analysis of habitat variables and a synthesis of species-related information into Habitat Suitability Index models for the white crappie.

This is one in a series of publications developed to provide information on the habitat requirements of selected fish and wildlife species. Numerous literature sources have been consulted in an effort to consolidate scientific data on species-habitat relationships. These data have subsequently been synthesized into explicit Habitat Suitability Index (HSI) models. The models are based on suitability indices indicating habitat preferences. Indices have been formulated for variables found to affect the life cycle and survival of each species. Habitat Suitability Index (HSI) models are designed to provide information for use in impact assessment and habitat management activities. The HSI technique is a corollary to the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures.

17. Document Analysis a. Descriptors

Habitability
Fishes

b. Identifiers/Open-Ended Terms

White crappie
Pomox annularis
Habitat
Habitat Suitability Index

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	Unclassified	22
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI–Z39.18) See Instructions on Reverse

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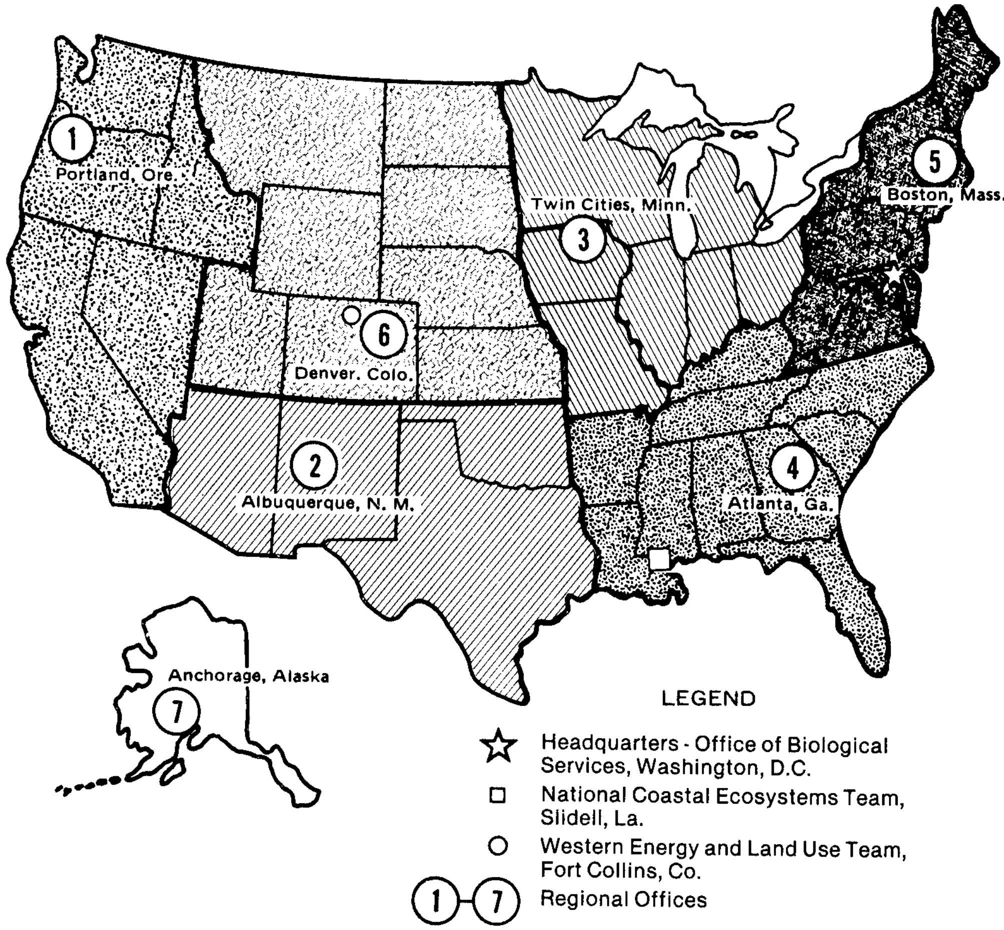

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This publication was printed at the UNICOR Print Plant,
Federal Correctional Institution, Ray Brook, NY